SAVE II “Fuel Cell Services” project

ISR-UC MVV Consultants and Engineers PACA Region COGEN Portugal

“*Providing Energy Services with Fuel Cells in a Liberalised Energy Market*”

Contract Nº. 4. 1031/Z/02-061/2002

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Assessment of results obtained in ongoing fuel cell distributed generation projects

- **European fuel cell projects.**

Programme	Title	Duration
FP5 - Energy, Environment, Sustainable Development	Progress in Coupling Biomass Gasification and MCFC Stack (CLEAN ENERGY FROM BIOMASS)	36 months
	Efficient and Clean Production of Electricity from Biomass via Pyrolysis oil and Hydrogen, utilizing Fuel Cells (BIOELECTRICITY)	36 months
	Fuel Cells and Hydrogen Improved R&D Strategy for Europe (FHIRST)	12 months
	The European Hydrogen (based) Society (HYSOCIETY)	24 months
	Numerical Fuel Cell Component Performance Prediction Tool (NFCCPP)	36 months

Source: *EUROPEAN COMMISSION. European Fuel Cell and Hydrogen Projects*

Objectives of the Project

Promotion of fuel cell energy services, **namelly combined heat and power (CHP), in the buildings sector and in industrial small and medium enterprises (SMEs)**, through the identification of cost-effective opportunities, by increasing the awareness of the benefits of fuel cell options, and by developing appropriate strategies to foster fuel cell energy services in those types of consumers.

Expected results of the project

This project is targeted at the penetration of fuel cells in buildings and in industrial SMES, which in the 3 countries involved, have an electricity consumption of over 350 TWh.

With the new distributed generation technologies, with a particular emphasis on fuel cells, about one fourth of those consumers can benefit from distributed generation.

About 10 Million TOEs of import fossil fuel can be saved per year, with a value of 2000 Million Euros. The associated CO2 savings reach over 20 Million tons per year. The potential impact in the all the EU would be two times larger.

Benefits of large scale implementation of fuel cells

- Reduction carbon dioxide emissions
- Decentralized generation may also mitigate the need for the expansion of the generation capacity, as well as transmission and distribution network, which may be particularly relevant in some congested urban areas of Europe
- Can be used to offer high reliability power supply to a growing number of customers who have stringent requirements on their power needs, in addition to provide valuable network services such as reactive power, frequency response or island mode operation

Phase 1: Analysis of energy services options in a liberalised market

Assessment of energy services options and of the key parameters influencing the market, **including:**

- **description of typical service packages offered by the utilities based on supply-side and demand-side management**
- **parameters sensitive to market liberalisation**
- **how did such parameters vary since market opening, and what was the influence on the energy service business**
- **survey of special conditions for promotion of DG and CHP applications**
- **Comparison of current legislation in the three countries involved, and influence**

Special conditions for the promotion of Decentralised Generation and CHP

- Public financial support (e.g. grants are provided on the basis of the energy and environmental value of the projects);
- Feed in laws for power from CHP (e.g. buy back contracts have developed as a special form to help support the process of liberalisation, buying obligations for electricity produced by renewable energy fed into the grid);
- Tax reductions (e.g. reduction of VAT from 17% to 12% on renewable equipment, custom duties exemption and income tax reductions).

Phase 2: Cost-benefit analysis methodology for fuel cell energy services

Development of cost benefit analysis methodology for fuel cell energy services:

• assessment of competing distributed generation technologies

• comparative analysis of peak costs of supply in relation to central generation

• assessment of various relevant support programmes and legislation, which reduce cost of distributed generation

• analysis of the influence of load pattern of typical clients for distributed generation electricity and the thermal demand (cooling and heating) variations in different buildings subsectors and in industrial SMEs

• evaluation of the contribution to the improvement of reliability and quality of service

• identification of market niches in which distributed generation with FC could become an economic solution

• assessment of results obtained in ongoing FC distributed generation projects

Fuel Cells : Overview (vol.1)

	PEMFC	PAFC	MCFC	SOFC
Commercially available	Yes	Yes	No	Yes
Power range	3-250 kW	100-200 kW	250kW -10 MW	1kW -10 MW
Fuel	Natural gas, hydrogen, propane, diesel	Natural gas, landfill gas, digester gas, propane	Natural gas, hydrogen	Natural gas, hydrogen, landfill gas, fuel oil
Efficiency without cogeneration	25-40%	36-42%	45-55%	45-60%
Environmental impact	Nearly zero emmissions			
Other features	Cogeneration			
Availability	Commercially available	Commercially available	Likely commercialisation	Commercially available

Fuel Cell Typical Applications

PEMFC	PAFC	MCFC	SOFC
• Car • PQ applications • DG in residencial buildings • mobile applications	• DG • Packaged systems with extremely high reliability • Industry • Hospitals • Commercial • Residential	• Large DG • Industrial • Government facilities • Universities • Hospitals	• Very large DG • Residential cogeneration • Small commercial buildings • Industrial facilities

Strengths and weakness of fuel cells

Advantages	Disadvantages
High efficiency	High initial costs
Low pollution	Fuel sensitivity
Low noise and vibration	Lack of maintenance experience
Good potentialities to cogeneration (clean hot exhaust)	Absence of a long history of commercial usage
Modular architecture	
Sitting flexibility	
Good load following capability	

Fuel Cell prices from manufacturers

Manufacturer	Model	Power kW	Capital Costs € / kW	Price €	Technology
Fortum Se	5kW	5	17000 - 20000	100000	SOFC
ONSI	PC25	200	5000	1000000	PAFC
IdaTech	4,6kW	4,6	16448	82240 *	PEMFC
Acumentrics	10kW	10	19900	199000 *	SOFC
AXANE	AXANE 2kW	2	12500	25000 *	PAFC
Plug Power	GenCore System	5	2466	12332	PEMFC
Proton Motor	2 stacks type PM600	2x11	19773	435000	PEMFC
Ballard	NEXA	1,2	7042	8450 *	PEMFC

* Does not includes commissioning and start up.

Cost-benefit analysis methodology for fuel cell energy services

Comparative analysis of peak costs of supply in relation to central generation:

- €/kW for central generation
- initial costs of distributed generation options (€/kW)
- value of ancillary services (reactive power, load following capabilities, etc....)

Capital costs for conventional power grid

Technology	€ / KW
Nuclear	1700-3000
Gas turbine	280-1200
CCGT	600-700
Coal	490-950 *
Hydro	1600-3000 **

* capital costs for coal power grid installation depends on the environmental legislation

** the value can differ roughly depending on the site conditions

Capital costs of distributed generation options (€/kW)

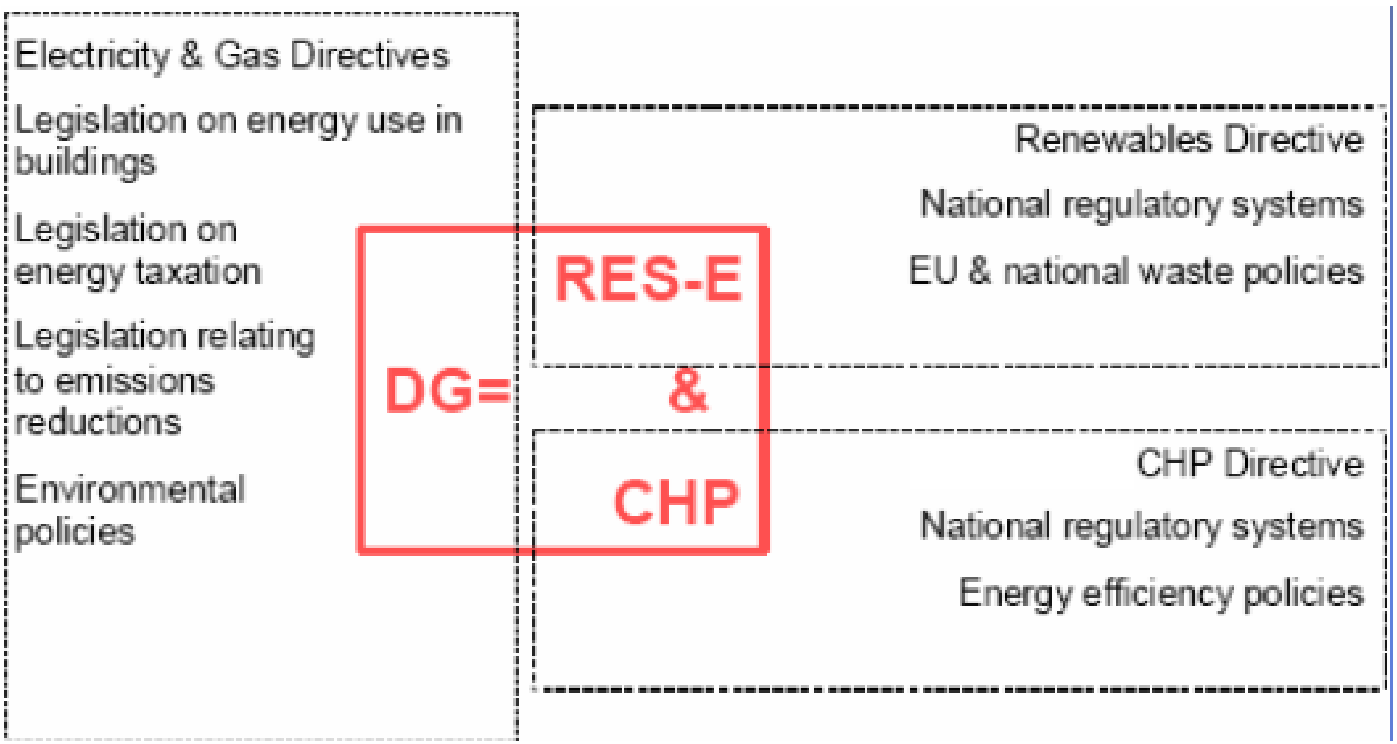
DG technology	Capital costs, €/kW	
	Projected	Present
PEMFC	1100-1800	2400-19000
PAFC	1350-1800	8500-10000
SOFC	1200-2000	13500-16000
MCFC	1200-2100	-
Microturbines	800-1500	
Combustion turbines	200-800	
Combustion turbines with CHP *	700-1000	
Reciprocating IC engines	200-750	
Stirling engines	1600-40000	
Renewable technologies - wind turbines	800-1200	
Renewable technologies – photovoltaics	4800-8000	

* CHP - combined heat and power (cogeneration)

Legal framework for DG

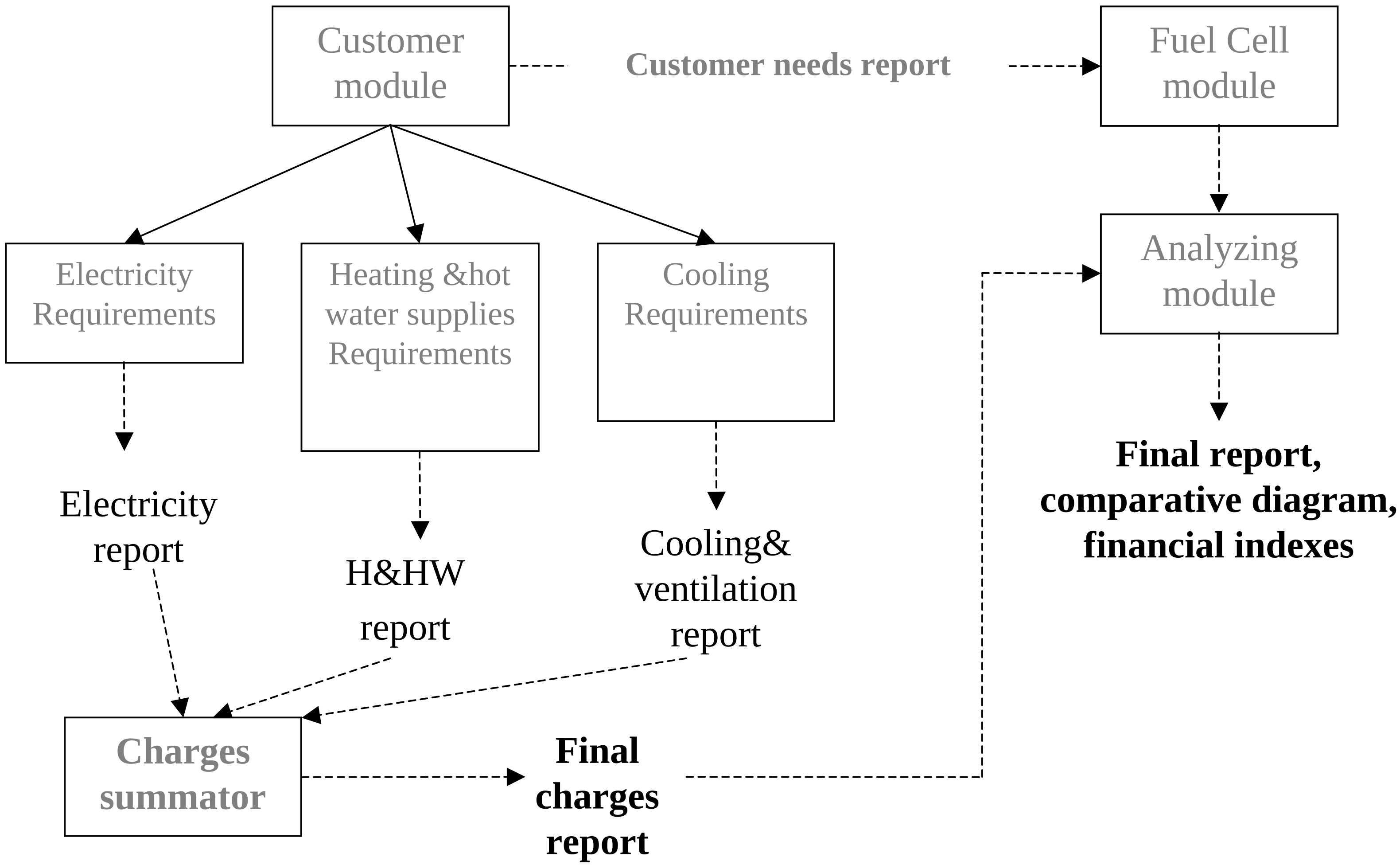
Specific DG policy in any EU Member State or at EU level does not exist. DG is subject to general electricity and gas market regulations, and also to specific legislation for renewables or CHP. In terms of EU energy legislation the Electricity Directive and the Gas Directive have general relevance to electricity producers using DG .

Legal and regulatory environmet for DG in the EU:



Methodology

Structure of the cost-benefit analysis software:



There are three main modules:

1- CUSTOMER MODULE: Contains information about customers consumption (electricity, heat and cooling), hourly profiles for a week for different seasons, and determines customers requirements for electric power, space heating and hot water supply, cooling and ventilation.

2- FUEL CELL MODULE: Provides the fuel cell option for each specific customer.

3- ANALYZING MODULE: Provides the cost-benefit analysis, and comparative cost analysis for conventional technologies and fuel cells, and generates the final assesment report.

CUSTOMER MODULE : INPUT DATA

- **Electricity Requirements**: customers electricity requirements and electric equipment characteristics (kW, kWh, V, average peak power requirements, reactive power, etc.)
- **Heating and Hot Water Requirements** : similar to electric module but for heat energy.

- **Cooling Requirements** : similar to electric module but for cooling technology.

Fuel cells specialization

- ***Base load devices***

Sizing driven by load duration and implementation

- ***Peak devices***

Most useful for higher peak demand customers with time-of-use rates

- ***Backup/standby ensuring***

Need for reliability allows for higher cost per kW units relative to base load applications

Some DG technologies specializations

	Microturbines	*Recip.Engines*	*Low-temp. fuel cells*	*High-temp. fuel cells*
Baseload	-	○	●	●
CHP	-	-	-	●
Peaking	●	●	○	○
Standby/ backup	●	●	-	●
Power quality	-	-	●	-

LOW ○ → ● **HIGH**

Source*: ADL*

Phase 3: Analysis of the distributed generation fuel cell market potential as well as the associated primary energy and carbon savings in the countries involved

- **evaluation of the market potential**
- **estimation of possible market penetration rates**
- **assessment of the cost-effectiveness of FC as well as associated impacts**

Potential DG technology applications

- **Continuous Power** (where DG is operated at least 6,000 hours per year)
- **Combined Heat and Power** (CHP) (where DG waste heat is used for heating and <u>or</u> cooling)
- **Peaking Power** (where DG is operated between 200-3000 hours per year during periods of high electricity price or high site demand)
- **Green Power** (where DG is operated by a facility to help reduce environmental emissions from its power supply)
- **Premium Power** (where DG provides a higher level of reliability and/or power quality than typically available from the grid)
- **Transmission and Distribution Deferral** (where DG is used to delay the purchase of new transmission or distribution systems)
- **Ancillary Service Power** (where DG is used to provide ancillary service at a transmission or distribution level; includes spinning / non-spinning reserves, reactive power, voltage control, and local area security)

Task 3: Main Conclusions

• Fuel Cells seem to have a promising future in some sectors, specially which have important power and thermal needs and natural gas consumption: hospitals, hotels, and collective housing at short term.

•Based on the economic analysis carried out for the case studies (one hospital and one hotel), the application of PEMFC to operate on peak hours (10o0 hours per year) and excluding cooling charges, is cost effective even at the present market conditions, with payback time of 10 years. If the price of fuel cells decrease to half the present price, then the payback will decrease to 5 years.

Phase 4: Analysis of market barriers

This phase will put special emphasis to distributed generation application by energy service companies, since private auto producing has turned out to be difficult (particularly for small and medium customers)

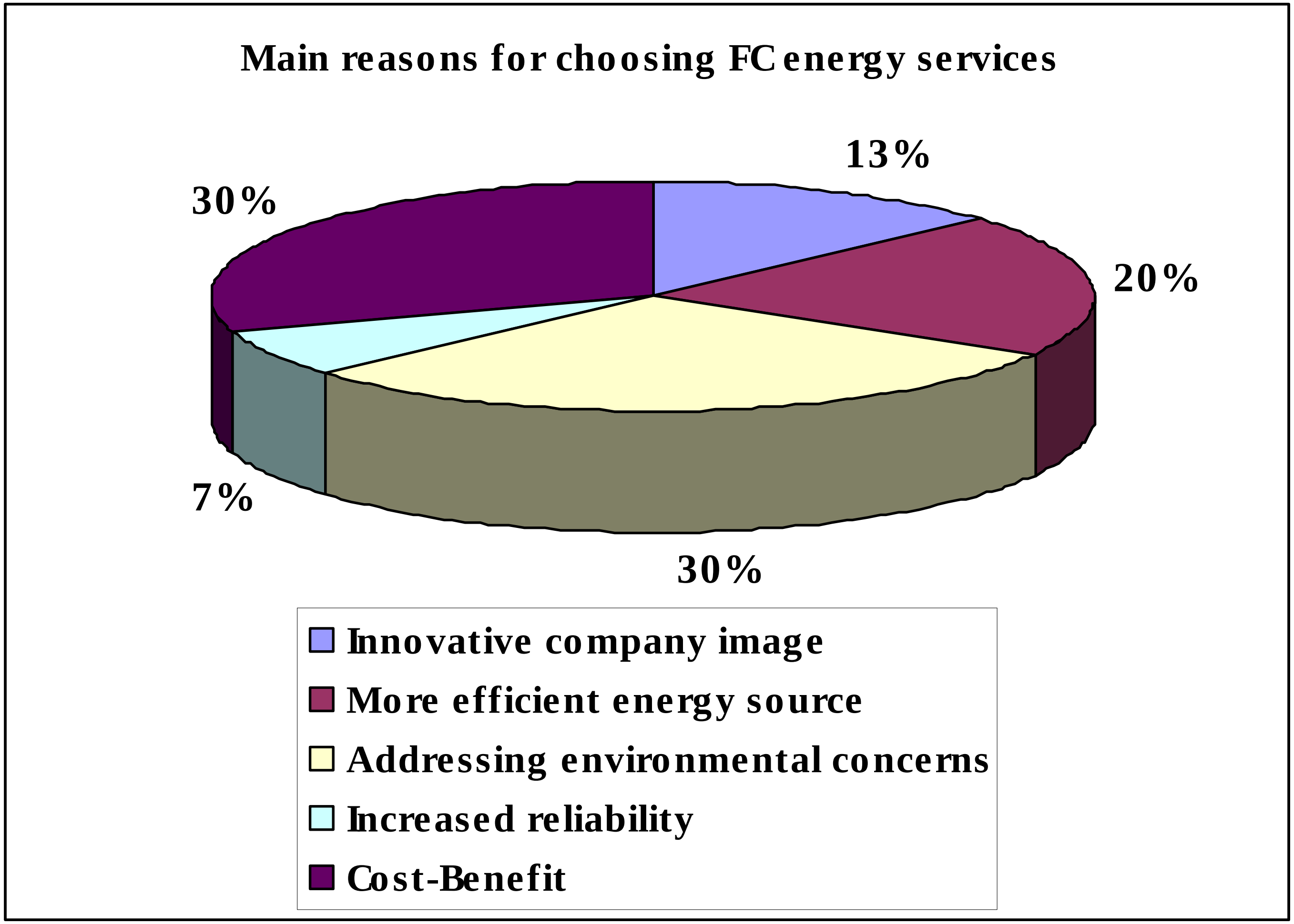
- **analysis of the barriers which prevent the large-scale adoption of fuel cell energy services in buildings and industrial SMEs**
- **comprehensive assessment of the barriers to fuel cell energy services application in the evolving energy market liberalisation, consisting of typical case studies, compendium on country and EU legislation, questionnaires on business practice of utilities**

Analysis of market barriers

Issues to be investigated

- Level of awareness
- Availability of technical skills and technical support
- Gas Network Availability (for fuel cell operation)
- Availability of capital
- Volatility of prices of oil and gas (external influence – war, iraq situation, OPEC)
- Too low electricity prices (for some countries more important than others)
- Too little thermal energy demand
- No standard contract procedures for provision by energy services companies
- Market liberalisation

Main reasons for choosing FC energy services



Phase 5 – Identification of possible strategies to promote fuel cell energy services

- **information and advertising campaigns**
- **training, in site assessment and assistance**
- **development of improving financing mechanisms**
- **legislation**
- **promotion of products**
- **availability of high reliability energy services**
- **agreements with manufacturers**
- **green electricity**
- **special regulation on distributed generation electricity prices**

What is Power Quality

- “The concept of powering and grounding electronic equipment in a manner that is suitable to the operation of that equipment and compatible with the premise wiring system and other connected equipment” (IEEE St-1100 Emerald Book)
- “Good” power quality is whatever electrical supply necessary for end-use to perform its intended function(s)
- Safety is a key issue and is an overriding factor

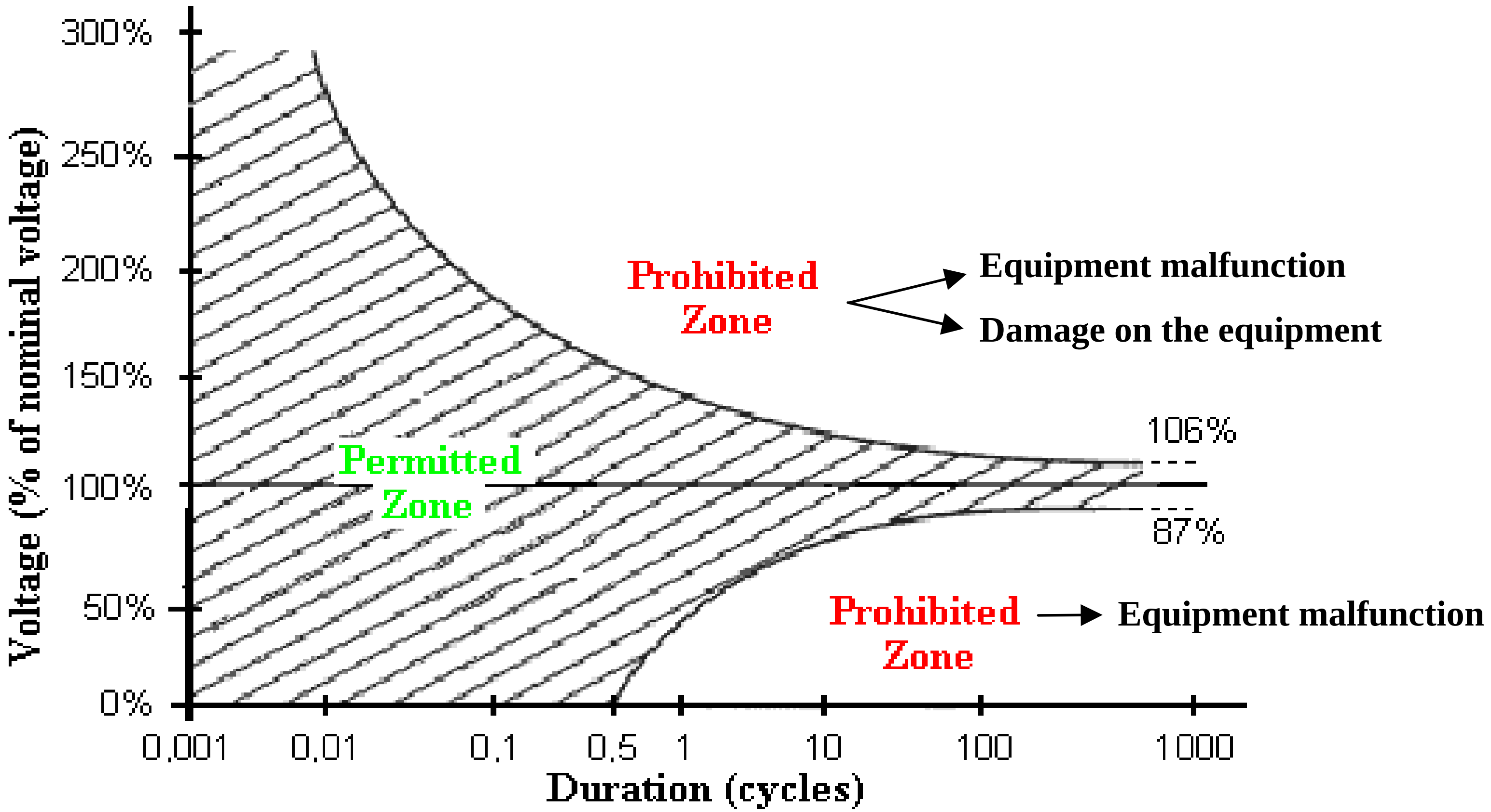
Main PQ problems

- Voltage sags
- Micro-interruptions
- Long interruptions
- Voltage spikes
- Voltage swells
- Voltage fluctuations
- Voltage unbalance
- Noise
- Harmonic distortion

CBEMA curve

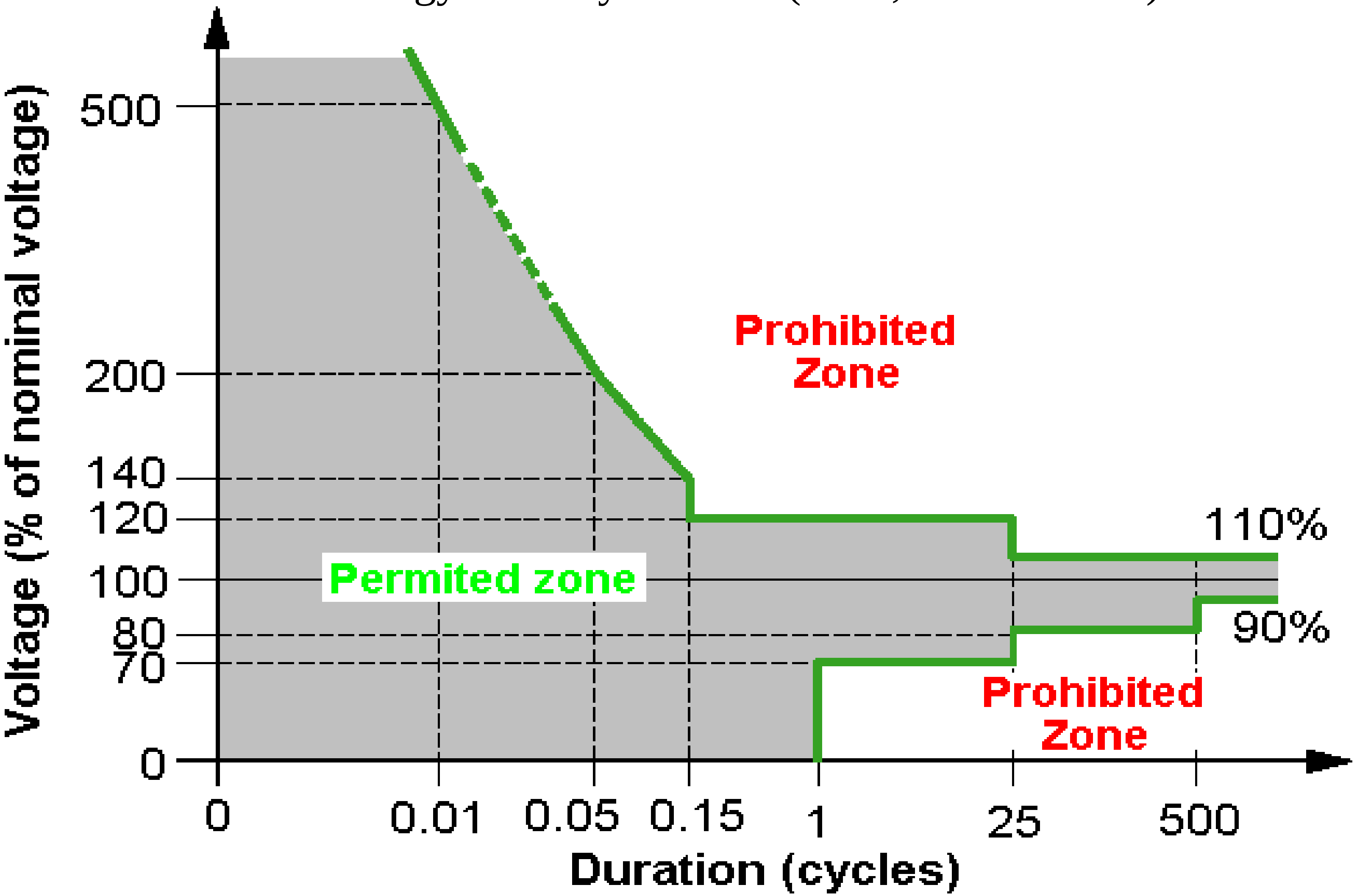
CBEMA – Computer and Business Equipment Manufacturers Association (1978).

Specifies the maximum and minimum limits that sensitive electronic equipment should be able to withstand.



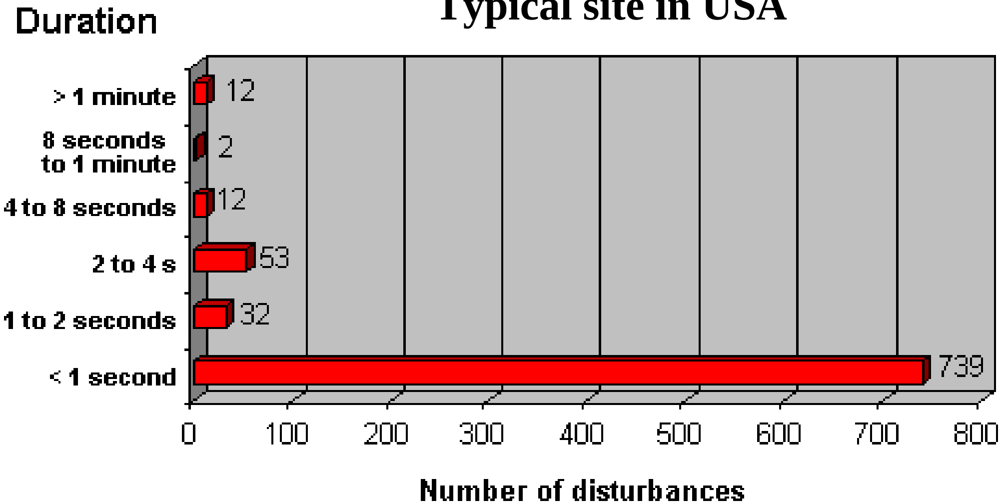
ITIC curve

ITIC – Information Technology Industry Council (1996, revised 2000).

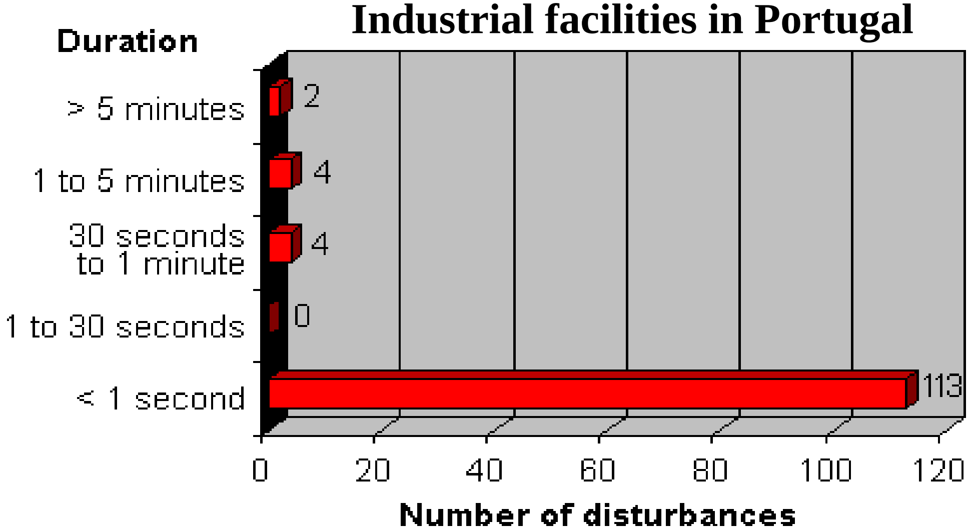


Power Quality characterization

Typical site in USA

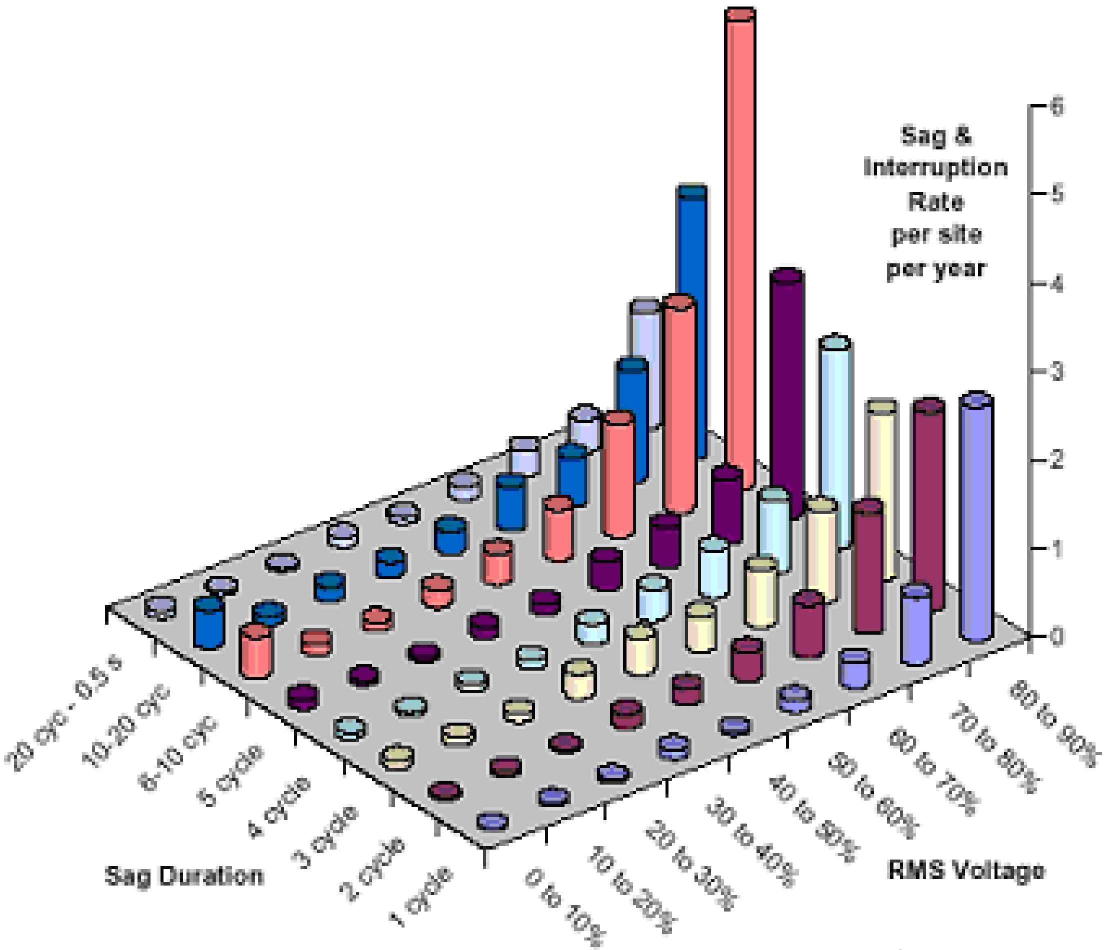


Industrial facilities in Portugal



In both cases, about 90 % of PQ events have duration below 1 second.

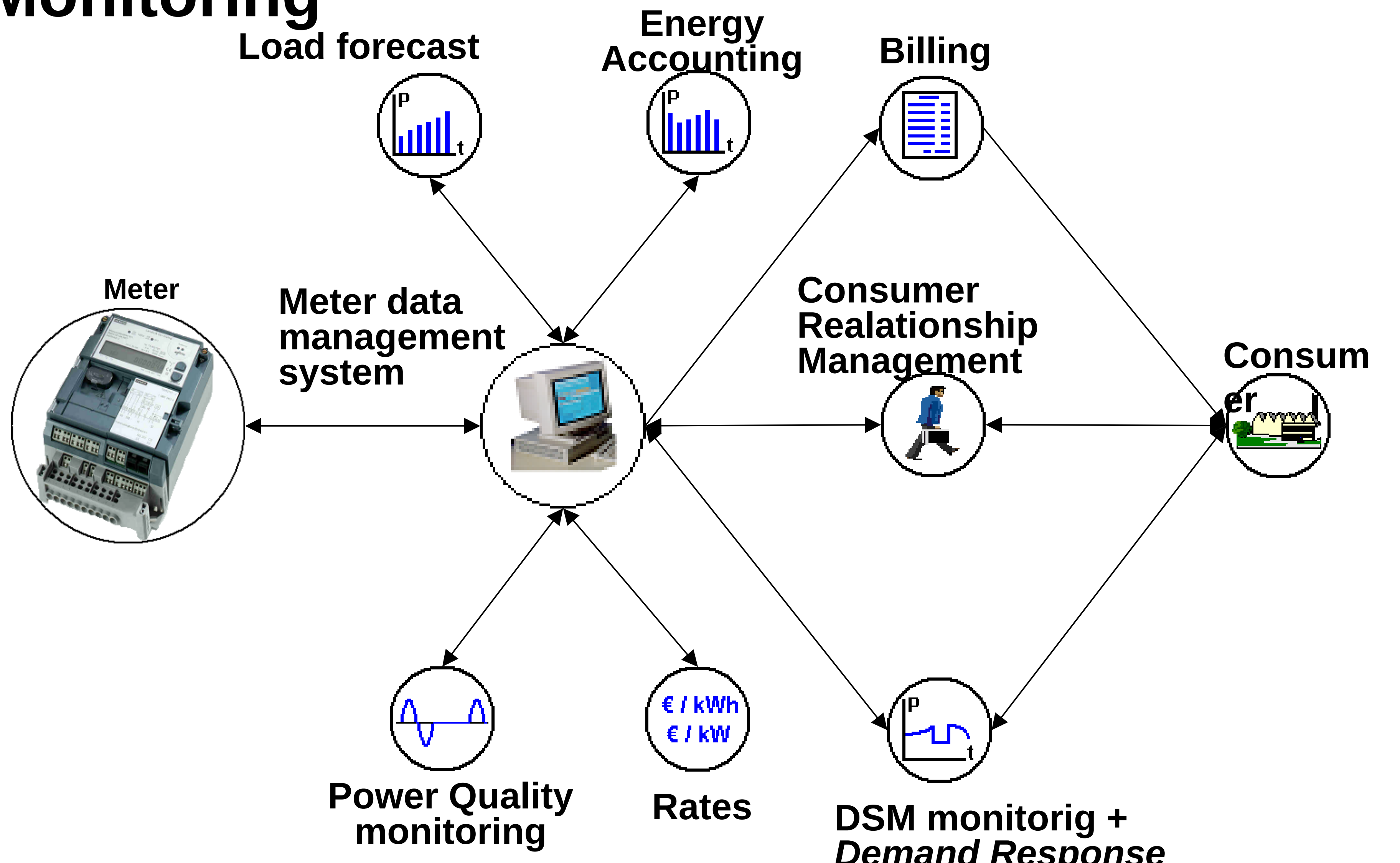
Power Quality characterization



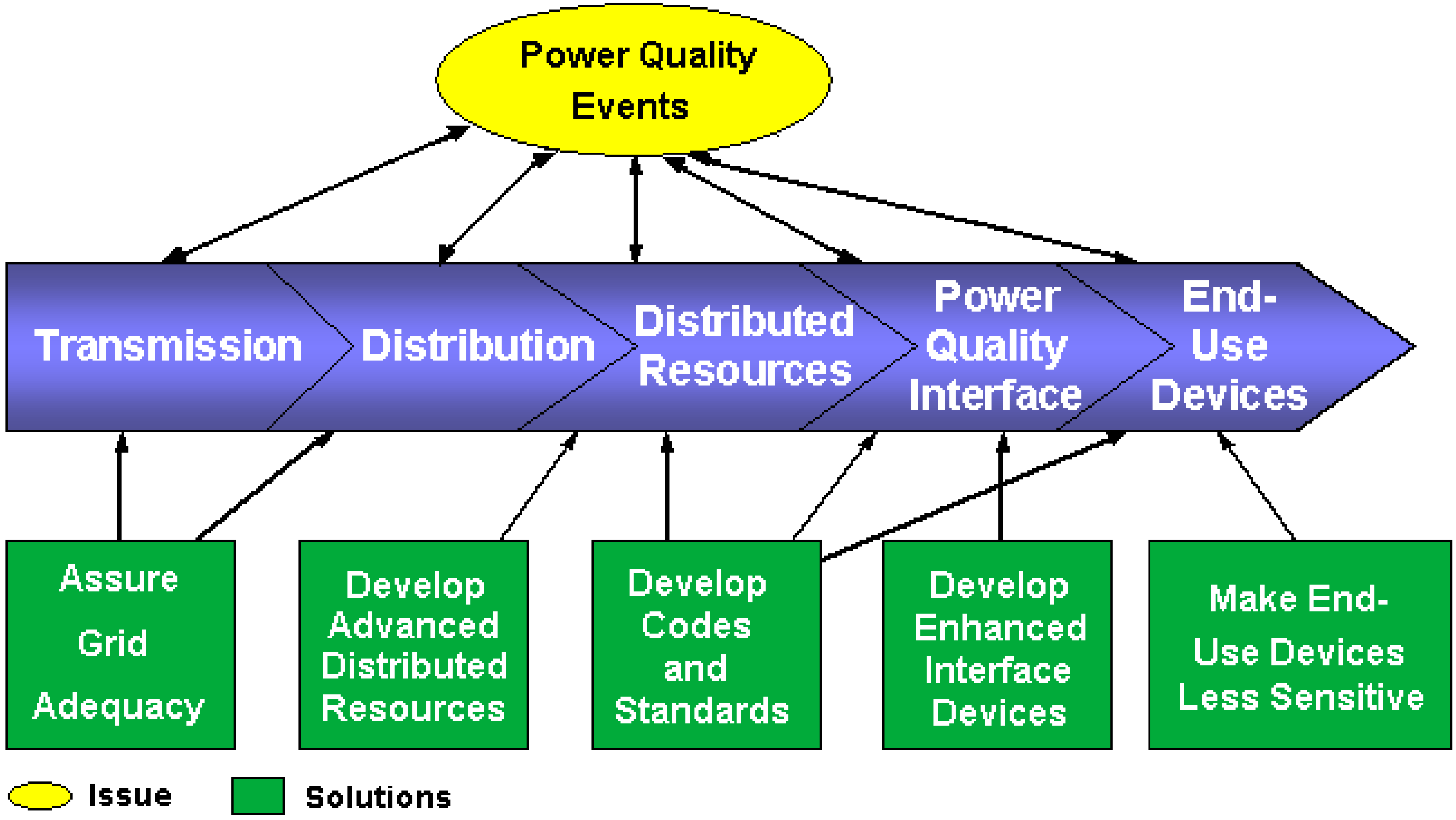
Source: EPRI

92% of PQ disturbances were voltage sags with amplitude drops up to 50% and duration below 2 seconds.

Telemetering for PQ Monitoring



Power Quality solutions



Power Quality costs

Direct costs

- Damage in the equipment
- Loss of production and raw material
- Salary costs during non-productive period
- Restarting costs

Indirect costs

- Inability to accomplish deadlines
- Loss of future orders

Non-material inconvenience

- Inconveniences that cannot be expressed in money, such as not listening to the radio or watch TV

Power Quality costs

- **Business Week (1991)** - 26,000 million USD per year in the United States
- **EPRI (1994)** - 400,000 million USD per year in the United States.
- **US Department of Energy (1995)** - 150,000 million USD per year for United States.
- **Fortune Magazine (1998)** - Around 10,000 million USD per year in United States.
- **E Source (2001**) - 60,000 to 80,000 USD per installation, per year for continuous process industries, financial services and food processing in the United States.
- **European Copper Institute (2001)** - 10,000 million EUR per year, in EU in industry and commerce.

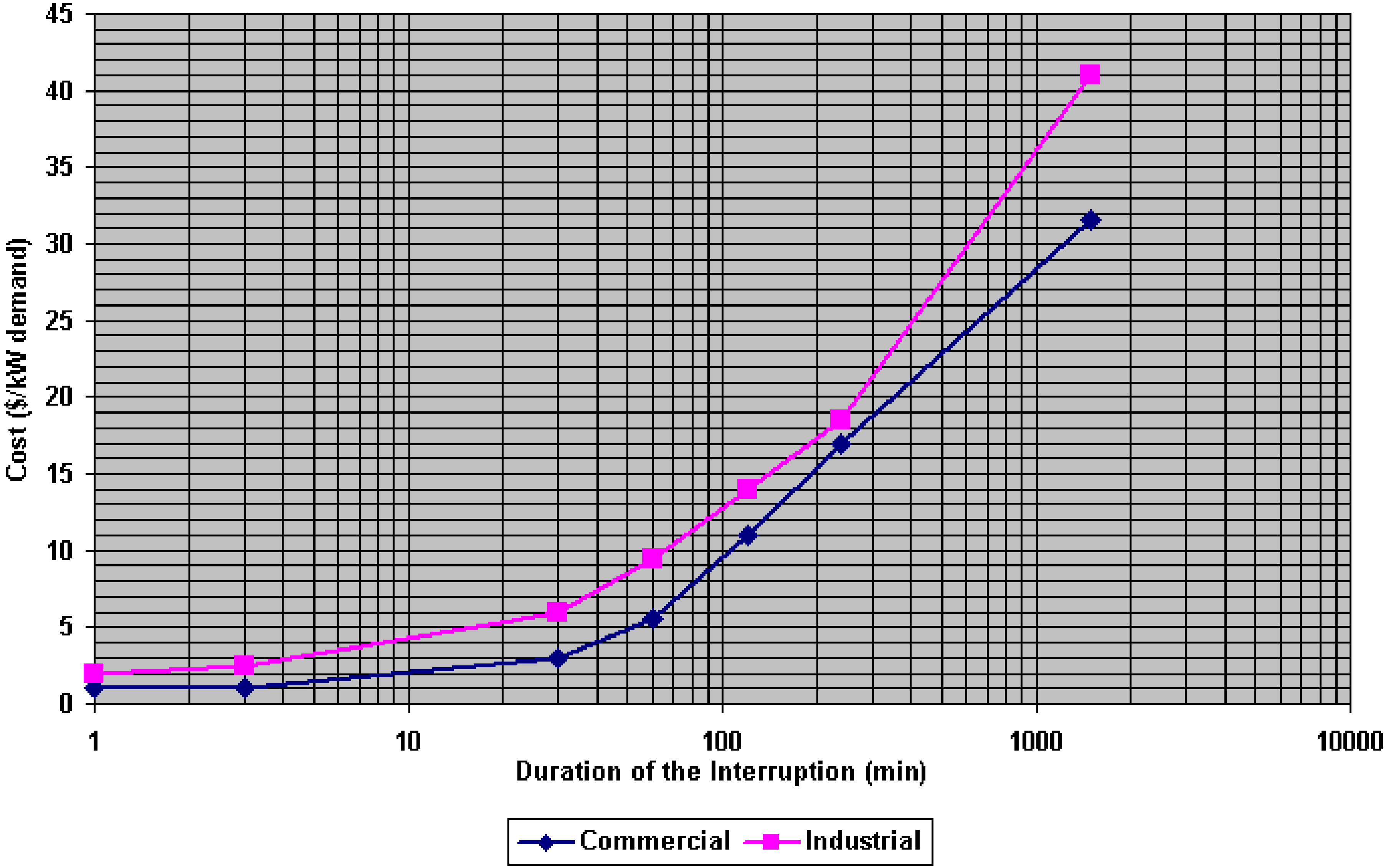
Power Quality Costs

Cost of momentary interruption (1 minute), in $/kW demand

	Minimum	Maximum
Industrial		
Automobile manufacturing	5.0	7.5
Rubber and plastics	3.0	4.5
Textile	2.0	4.0
Paper	1.5	2.5
Printing (newspapers)	1.0	2.0
Petrochemical	3.0	5.0
Metal fabrication	2.0	4.0
Glass	4.0	6.0
Mining	2.0	4.0
Food processing	3.0	5.0
Pharmaceutical	5.0	50.0
Electronics	8.0	12.0
Semiconductor manufacturing	20.0	60.0
Services		
Communication, information processing	1.0	10.0
Hospitals, banks, civil services	2.0	3.0
Restaurants, bars, hotels	0.5	1.0
Commercial shops	0.1	0.5

Source: Electrotek Concepts

Power Quality costs



Source: Electrotek Concepts